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ABSTRACT

Rapid and surprising changes in technology commercialization have made predicting employment in California much more difficult in recent years. Planning in all areas in which governmental services are provided has been hurt as a result. To provide new data for planning, the opinions of California industrial experts (primarily venture capitalists) were sought concerning what inventions or scientific breakthroughs are likely to be significantly commercialized in the 1980s, and concerning how those technologies will affect employment in California. Technologies cited as of emerging importance were in the fields of computer science, biological engineering, electronics, electro-optics, energy, materials, and a few others. Nineteen of these technologies affecting the workforces in automation, communications and information, energy, new materials, and agriculture and biological engineering are analyzed in this document in terms of what they are, how they are used, when their use will become commercially significant, and what barriers and incentives exist affecting their commercialization. These technologies will have a direct employment impact and will affect employment in industries using the new products or process, the very existence of some occupations, and the solving of problems in the public sector. (Author/PGD)

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California's Technological Future:

Emerging Economic Opportunities in the 1980s

High Technology and the California Workforce in the 1980s

EA 014 719

Department of Economic and Business Development
Edmund G. Brown Jr., Governor

CALIFORNIA'S TECHNOLOGICAL FUTURE:
EMERGING ECONOMIC OPPORTUNITIES IN THE 1980s

HIGH TECHNOLOGY AND THE CALIFORNIA WORKFORCE IN THE 1980s

MARCH 1982

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EMPLOYMENT DEVELOPMENT DEPARTMENT

STATE OF CALIFORNIA

The opinions expressed herein are solely those of SRI International and do not necessarily represent the views of the State of California. Further, analyses contained herein of the commercial growth potential of various new technologies in no way constitute endorsements or investment recommendations on the part of the State of California.

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EXECUTIVE SUMMARY

The number of workers affected by newly commercialized technology is likely to be far greater in the 1980s than it was during the 1970s. During the 1980s the major employment impacts will be from the rapidly expanding applications of technology, not just the manufacture of new technologies. While aggregate employment growth is likely to continue, many individual industries and occupations are likely to experience declining employment.

Technology is both a threat and an opportunity for the California economy. The overall health of the California economy depends on the continued development of new technologies. Maintaining its technical lead means general economic prosperity, assistance for some potentially troubled industries (such as agriculture), and solution to some of the state's transportation, energy, and water problems. On the other hand, technical change will accelerate the decline of some older industries and traditional occupations. Handling displaced industries and workers while assisting the growth of new industry will be an increasingly serious challenge to the state's economy during the next decade and well into the 1990s. Although the challenge of change is great, any attempt to slow technical change would result in the loss of both old and new industries.

California government can help or hinder the state's technological leadership position. To assess which technologies are most likely to be commercialized in the 1980s,and to anticipate the effect on employment in California, SRI International conducted interviews with key industrial experts, particularly venture capitalists. Specifically, venture capitalists interviewed cited the following factors that will encourage or discourage the expected new commercializations to be conducted primarily in California (as was the integrated circuits semiconductors electronics development).

SOME FACTORS AFFECTING COMPARATIVE ADVANTAGE OF CALIFORNIA
AS A CENTER OF HIGH TECHNOLOGY

Factor	Status
Strong universities	. Threatened by state andfederal cutbacks
	. Seeking R&D partnerships and other sources of industry funding
Strong venture capital market	. Rapidly expanding as a result of changes in state and federal tax laws
	. Ventures do not pay off quickly
Attractive environment for recruiting workers	. Hindered by housing costs
	. Transportation difficulties increasing
Attractive environment for business expansion	. Hindered by local and some state regulations on industrial construction.

I INTRODUCTION

The 1980s are likely to be an era of surprising expansions, contractions, and displacements of large numbers of California workers. A major force that is likely to produce these workforce changes is newly commercialized technology. Such technological "surprises" have already affected California's economy. For example, the electronics industry, spurred by the very rapid commercialization of integrated circuit semiconductors, dramatically altered the growth rate in Santa Clara county's "Silicon Valley." The rates of industrial plant expansion, new job and occupation creation, and increases in housing demand far exceeded the most extreme expectations or predictions of state, county, and city planning officials.

The 1980s hold promise of similar surprises, some positive and some negative. For example, by the late 1980s the "bioengineering revolution" may be a repeat of the semiconductor revolution. Key discoveries in both fields were made at Stanford University and the University of California. The most dramatic new high technology company to go public, Genentech, is a California biotechnology firm. A scientific breakthrough in recombinant DNA, with its many implications for medicine, agriculture, industrial materials, and so on, could easily create hundreds of occupations that do not yet exist and could employ tens of thousands. In particular, DNA technology is likely to have major impacts on California agriculture. Conversely, robotics developments, which are building on the rapid progress in computer-aided design (CAD) and factory automation including robots and computer-aided manufacture (CAM), will displace thousands of workers from some manufacturing jobs.

The Problem

For government and public utilities to effectively plan ahead for needed public services such as training schools, transportation, water, sewage service, and so forth, it is desirable to have accurate forecasts of the types and numbers of people that will need those services. The rapid and surprising changes in technology commercialization have made predicting employment much more difficult in recent years. In particular, extrapolation from historical trends and basic economic conditions cannot anticipate the changes triggered by new technology.

In this context, the problem addressed in this project was two-fold:

(1) To anticipate which inventions or scientific breakthroughs will be significantly commercialized in the 1980s.

(2) To anticipate how those newly commercialized technologies will affect the types and levels of employment in California.

Objective

To shed light on the above problem, this project gathered the opinions of California industrial experts, primarily venture capitalists, concerning which technologies will alter the types or levels of employment in key California employment sectors. Using this information, SRI then analyzed the extent to which the concensus of these experts (as gathered through interviews and the project's conferences) is reflected in the baseline employment projections currently available.

Method of Approach

To accomplish these objectives, SRI undertook three basic tasks:

- An assessment of emerging technologies, using the judgement of technology experts at SRI and elsewhere in California
- A review of which of these technologies would most likely be commercialized during the 1980s, using comments made by venture capitalists in light of two technology assessment conferences
- Analysis of the impacts of these technologies based on a comparison of the technology employment potential with current state employment projections

II EMERGING TECHNOLOGIES

At no time in history has there been a broader range of new inventions and technologies poised for commercial development and diffusion. Exhibit 1 lists the technologies and applications that will be significant in California in the 1980s, as suggested by technical experts.

A review of Exhibits 1 and 2 indicates that the range of emerging or fast-growing technologies is broad, diverse, and advancing with increasing rapidity. Similarly, the range of applications of these technologies is continuously expanding. There is as much invention in the applications area as there are in the technologies themselves. The result is that the relative cost of goods in the marketplace is shifting. Electronics, communication, and information are getting cheaper, while energy and other physical resources are getting more expensive.

The number and variety of technologies are so great that it was not possible to be exhaustive. (For a more thorough review of technology and its potential, see The Five-Year Outlook: Problems, Opportunities and Constraints in Science and Technology, National Science Foundation, May 1980.) Rather, we have been selective from the items in Exhibit 1, relying on the technical experts to produce a respresentative list of technologies important to California in the 1980s. Technologically expert readers will undoubtedly each find areas they feel we should have included. However, the list we chose to analyze in depth is sufficient to point out some of the problems and opportunities for the state in planning to meet its changing workforce requirements over the next decade. For discussion convenience we have clustered these technologies into five basic categories (see Table 1).

Exhibit 1

EMERGING TECHNOLOGIES

COMPUTER SCIENCE

- Artificial intelligence
- High-level language
- Digital signal processing
- Speech synthesis
- Speech recognition
- Speech understanding
- Digitization
- Packet switching
- Computer-aided design
- Robots
- Expert systems

BIOLOGICAL ENGINEERING

- Recombinant DNA
  - Insulin (Human)
  - Gene therapy
  - Interferon
- Hybridoma
- Tissue culture
- Enzymes
- Growth hormones/vaccines
- Food supplements
- Embryo transfer
- Micropropagation
- Aquaculture
- Fermentation
- Soil-free cultures
- Irradiation

ELECTRONICS

- Microprocessors
- Memory devices
- Logic arrays
- Sensors
- Production equipment
- Josephson junctions
- VLSI lithography
- Gallium arsenide
- Bubble memory
- Transponders
- Earth stations
- Microwave

ELECTRO-OPTICS

- Lasers
- Displays
- Fiber optics
- Optical disc
- Optical computers
- Semiconductor lasers

ENERGY

- Photovoltaics
- Nuclear fusion (hybrid)
- Synfuels
  - Methanol
  - Ethanol
- Fuel cells
- Solar hot water
- Advanced fission
- Geothermal

MATERIALS

- Polymers
- Thin films
- Superconductors (Cryogenic)
- Metal matrix alloys
- Ceramics
  - High-temp/structional
  - Fiber reinforced
  - Metallic glasses
  - Solid electrolytes
- Metals
- Cutting/forming
- Assembly
- Test and inspection
- Bearings
- Brazing alloys
- Pressure vessels

MISCELLANEOUS

- Ultrasound
- Surface properties
- Membrane technologies
- Supercritical fluids
- Controlled atmosphere
- Ocean Mining

Exhibit 2

APPLICATIONS

ELECTRONICS

- Computers
- Printers, plotters
- Data storage
- Terminals
- Instruments
- Guidance systems
- Personal computers
- Silicon foundries
- FAULT-TOLERANT CHIPS
- Sensors

COMMUNICATION

- Computer software
- Video recorders
- Modems
- Digital PBX
- Satellites
- CAD systems
- OCR equipment
- Local networks
- Instrumentation
- MIS systems
- Information utilities
- Recording heads
- Cable sheathing
- Word processors
- Cryptography

AGRICULTURE

- Improved plant species
- Improved animal species
- Food processing
- Ingredients
- Salt tolerance
- Disinfestation
- Preservarion
- Deyhdration
- Cooking

CHEMICALS

- Biocatalysts
- Fine chemicals
- Waste management
- Proof testing
- Filtration
- Extraction of contaminants

HEALTH

- Drugs
- Diagnostics/tests
- CAT scanners
- Non-invasive testing
- Microsurgery
- Treatment therapies
- Implants

MINERAL EXTRACTION

- Mining
- Oil recovery

TRANSPORTATION

- Aircraft
- Jet engines
- Lightweight structures
- Rocket engines
- Heat engines

ENERGY SOURCE

- Heat exchangers
- Transformer cores
- Photovoltaic arrays
- Batteries
- Fusion reactors
- Wind generators
- Fuels
- Small hydro
- Heat pumps
- Energy management control
- Cogeneration

OTHER AREAS OF APPLICATION

- Consumer goods and services
- Construction
- Defense
- Education

Technology Review

For each of the 19 technologies cited in Table 1, the following exhibits (3 - 22) present the results of our four basic questions about new technology:

- What is the new technology?
- How is it used?
- What are the barriers and incentives to commercialization?
- When will significant commercial use begin?

These results were presented to state government representatives and venture capitalists on December 4, 1981. To each exhibit, we have added commentary concerning implications for California and commercialization rate suggestions of the venture capitalists interviewed.

Table 1

REPRESENTATIVE TECHNOLOGIES SIGNIFICANTLY AFFECTING CALIFORNIA'S WORKFORCE IN THE 1980s

Communication/Information

- Optical disks
- Broadband communication
- Computers
- Electronic media

Automation

- Sensors
- Computer-Aided Design (CAD)
- Industrial robots
- Factory automation
- Artificial intelligence-expert systems

Energy

- Heat pumps
- Photovoltaics
- Cogeneration
- Energy management and control systems

New Materials

- Metallic glasses
- High-temperature structural ceramics
- Solid electrolytes

Agriculture and Biological Engineering

- Irradiation
- Tissue culture/micropropagation
- Recombinant DNA

Exhibit 3

OPTICAL DISKS

STORAGE OF ANALOG OR DIGITAL INFORMATION ON LIGHT SENSITIVE RATHER THAN MAGNETIC MEDIA

ADVANTAGES

- PERMANENT ARCHIVAL PROPERTIES
- HIGH DENSITY (10^{10} BITS/SIDE)
- LOW-COST MEDIA
- MODERATELY RAPID ACCESS

DISADVANTAGES

- HIGH COST OF READ/WRITE HARDWARE
- GENERALLY NON-ERASABLE

APPLICATIONS

- DATA ARCHIVING
- AUDIT TRAIL RECORDING
- VIDEO AND AUDIORECORDING
- DIGITAL RECORDING

MARKETS

- HOME VIDEO
- HIGH FIDELITY
- CAI MATERIALS (TRAINING)
- ELECTRONIC FILE SYSTEM

BARRIERS TO COMMERCIALIZATION

TECHNICAL

- DIFFICULT TO ERASE
- COMPLEXITY OF HARDWARE

NON-TECHNICAL

- LOW-PRICE OF ALTERNATIVES
- LACK OF UNIFORM STANDARD
- DEVELOPMENT OF PROGRAM MATERIAL

TIME FRAME

- VIDEO PLAYERS — NOW
- DIGITAL HIGH FIDELITY — 1982
- DIRECT READ AFTER WRITE — 1982-
- ERASABLE DISK — 1985 (?)

Implications Relevant to California's Economy:

- Will restructure the publishing and archiving industries.
- Competition and some displacement of the magnetic memory industry.
- Restructuring of audio record/tape industry.
- Restructuring of public and private libraries.

Venture Capitalist's Comments:

- A moderate to high near-term commercial product whose rate of commercialization depends on solving current technological problems of reading data from and writing new data on the same piece of material ("read-write"), and efficient accessing.

Exhibit 4

BROADBAND COMMUNICATION

(SATELLITES, FIBER OPTICS, COAXIAL CABLE, MILLIMETER WAVES)

ADVANTAGES

- VIDEO IMAGES
- GRAPHICS
- HIGHSPEED DATA
- LARGE CAPACITY MULTIPLEXING

DISADVANTAGES

- DIFFICULT TO SWITCH
- MULTIPLEXING DIFFICULTIES

APPLICATIONS

- VIDEO BROADCAST
- INTERACTIVE CABLE SYSTEMS
- COMPUTER NETWORKS
- VIDEO TELEPHONY

MARKETS

- HOME VIDEO
- TELECONFERENCING
- COMPUTER COMMUNICATIONS
- BUSINESS NETWORKS
- MOBILE OR AREA COMMUNICATIONS

BARRIERS TO COMMERCIALIZATION

TECHNICAL

- SUFFICIENTLY POWERFUL SATELLITES
- NO BROADBAND SWITCHES
- NO FIBER MULTI-DROP POINTS

NON-TECHNICALS

- FCC BROADCAST REGULATIONS
- AVAILABLE RADIO SPECTRUM
- EXISTING TELEPHONE PLANT

TIME FRAME

- DIRECT BROADCAST SATELLITE — 1982-85
- FIBER OPTIC TRUNKS — 1981
- FIBER OPTIC DISTRIBUTION — ?
- MILLIMETER WAVE DISTRIBUTION NETWORK — 1983-84

Implications Relevant to California's Economy

- California is likely to be a major supplier of:
  - (a) Equipment
  - (b) Business and entertainment content.

Venture Capitalists' Comments:

. This is a highly diverse sector with many specific opportunities and some severely limited areas. Satellite-related hardware is a clear opportunity for new ventures, while system operations remains more risky, because of changing regulatory environment.

Exhibit 5

COMPUTERS

COMING (5th) GENERATION SYSTEMS CHARACTERIZED BY:

VERY LARGE SCALE INTEGRATION (VLSI) PLUS;

- COMMUNICATION IN THE ARCHITECTURE
- PARALLEL PROCESSING
- SOFTWARE ENGINEERING
- ARTIFICIAL INTELLIGENCE (AI)
- PATTERN RECOGNITION

ADVANTAGES

- GREATER COMPUTING POWER
- LOWER COST PER CAPABILITY
- WIDER VARIETY OF FUNCTIONS
- USER FRIENDLY INCLUDING HIGHER ORDER LANGUAGE AND EASIER INPUT/OUTPUT

DISADVANTAGES

- INCREASED PRIVACY AND SECURITY CONCERNS
- HIGH RATE OF OBSOLESCENE

APPLICATIONS

- WEATHER FORECASTING
- INFORMATION PROCESSING
- SPEECH UNDERSTANDING
- PERSONAL COMPUTING
- AUTOMATION
- PROCESS CONTROL
- DIGITAL SYSTEM DESIGN

MARKETS

- AGRICULTURE
- FRIENDLY OFFICE SYSTEMS
- HOME ENTERTAINMENT
- FACTORY OPERATIONS
- SOFTWARE DEVELOPMENT
- CAD/CAM

Barriers to Commercialization

TECHNOLOGICAL PROBLEM AREAS

- SYSTEM COMPLEXITY
- SOFTWARE DEVELOPMENT COSTS
- COST OF SYSTEM DESIGN
- INTERFACE DESIGN

NON-TECHNICAL

- SHORTAGE OF ELECTRONIC ENGINEERS
- SHORTAGE OF PROGRAMMERS
- LIMITS ON BASIC R&D SUPPORT (VIS-A-VIS JAPAN)

TIME FRAME

CONTINUOUS WITH INCREASED FOREIGN COMPETITION

Implications Relevant to California's Economy:

- Speech recognition will revolutionize telephone-based response systems (eliminate most operators).
- Renewed rapid decline in computing costs could open new EDP services to households (accounting, etc.).
- Much more employment in computer-based services areas--small business opportunities.

Venture Capitalists' Comments:

- This is a growth area for California. The commercial impact of new systems will come from two directions:
  - Advancing small business and personal computers which offer major new small venture opportunities.
  - The development of major new large systems which is an area that will be dominated by large U.S. and Japanese firms and by government/military spending.

Exhibit 6

NEW ELECTRONIC MEDIA

NEW INFORMATION PRODUCTION AND DISTRIBUTION SERVICES

ADVANTAGES

- LOWER COST OF INFORMATION
- BROAD AND RAPID DISTRIBUTION
- MORE DIVERSITY OF DATA SOURCES AND DISPLAYED
- NEW ARTISTIC MEDIA
- INCREASED USER CONTROL OF CONTENT (RANDOM ACCESS)

DISADVANTAGES

- INCREASED SOCIAL REQUIREMENT FOR INFORMATION AND TECHNICAL LITERACY
- CONCERNS FOR NATIONAL CULTURAL INTEGRITY

APPLICATIONS

- TELEDON/TELETEXT
- POINT OF SALE INVENTORY
- ELECTRONIC MAIL
- INFORMATION UTILITIES

MARKETS

- BROADCASTING
- NEWS SERVICES
- EDUCATION
- ENTERTAINMENT
- RETAILING
- PROFESSIONAL KNOWLEDGE BASES

BARRIERS TO COMMERCIALIZATION

TECHNOLOGICAL

- AUTOMATION OF COMPLEX SYSTEMS
- NO LOW-COST UNIVERSAL, STANDARD DISTRIBUTION

NON-TECHNOLOGICAL

- TRANSBOARDER DATA FLOW REGULATIONS
- COPYRIGHT PROTECTION
- ANTITRUST RESTRAINTS (AT&T)
- LACK OF CONTENT MATERIAL IN APPROPRIATE FORM

TIME FRAME

EMERGING TODAY WITH CONTINUOUS RAPID GROWTH THROUGHOUT THE 1980s

Implications Relevant to California's Economy:

- Rapid increase in demand for entertainment products
- Potential for California to become a major source of Hispanic and Asian entertainment
- Rapid increase in California based Technical and Business Information Services
- California will emerge as one of a small number of World News Centers
- California will be a major supplier of these distribution systems.

Venture Capitalist's Comments:

- Undoubtably, the production of new content, (be it software, electronic games, or other forms of entertainment) will be a very rapidly growing industry. The venture capital opportunities, however, are limited because it is difficult to assess in advance whether the new product can be successfully developed or whether it will sell.

Exhibit 7

SENSORS

- TRANSLATE PHYSICAL/CHEMICAL CHARACTERISTICS INTO ELECTRONIC SIGNALS
- PROVIDE INPUT SIGNALS FOR COMPUTER-BASED MEASUREMENT AND CONTROL SYSTEMS

ADVANTAGES

- HIGH VOLUME, LOW COST
- COMPATIBLE WITH INTEGRATED CIRCUIT (IC) TECHNOLOGY

APPLICATIONS

- MEASUREMENT OF FLOW, LEVEL, PRESSURE, TEMPERATURE, FORCE, DISPLACEMENT, pH, LIGHT, ETC.

DISADVANTAGES

- ENVIRONMENTAL SENSITIVITY
- LAG MICROPROCESSOR DEVELOPMENT

MARKETS

- MEDICAL INSTRUMENTS
- AUTOMOBILES
- CONSUMER APPLIANCES
- METALWORKING-ROBOTS
- PROCESS CONTROL
- SECURITY SYSTEMS
- POLLUTION CONTROL

BARRIERS TO COMMERCIALIZATION

TECHNICAL

- YIELDS (PRICE)
- PACKAGING
- APPLICATION DIVERSITY

NON-TECHNICAL

- REGULATORY UNCERTAINTY
- MICROELECTRONICS GROWTH

TIME FRAME

- SIMPLER SENSORS NOW COMMERCIALIZED
- PROLIFERATION OF APPLICATIONS THROUHOUT DECADE OF 80s
- SOPHISTICATED, MULTI-INPUT, INTELLIGENT SENSORS UNDER DEVELOPMENT

Implications Revelant to California's Economy

- Most manufacturing, mining, and agricultural industries will adopt much more complex feedback and control systems.
- Complexity of most household/auto equipment will increase (greater demand for more thoughtful design).
- Shift in quality control philosophy and practice to 100 percent testing.

Venture Capitalists' Comments:

- As with all technologies connected with automation, this is a very hot area for commercial development.

Exhibit 8

COMPUTER AIDED DESIGN (CAD)

- APPLICATION OF INTERACTIVE COMPUTER GRAPHICS TECHNOLOGY TO THE DESIGN OF PRODUCTS/PROCESSES
- SIMPLE LOW COST STANDALONE VIDEO TERMINALS TO COMPLEX INTERCONNECTED CAD/CAM SYSTEMS

ADVANTAGES

- REDUCES DESIGN TIME
- SIMPLIFIES DESIGN CHANGES
- FACILITATES DESIGN ANALYSIS

DISADVANTAGES

- REQUIRES NEW SKILLS
- UPSETS EXISTING DOCUMENTATION AND INFORMATION PROCEDURES

APPLICATIONS

- IC DESIGN
- MECHANICAL DESIGN/DRAFTING
- FACILITIES PLANNING

MARKETS

- ELECTRONICS
- AUTOMOTIVE
- AEROSPACE
- ENGINEERING & CONSTRUCTION

BARRIERS TO COMMERCIALIZATION

TECHNICAL

- SOFTWARE DESIGN/COMPATIBILITY
- DATABASE DEVELOPMENT
- SYSTEM INTEGRATION

NON-TECHNICAL

- PURCHASE & IMPLEMENTATION COST
- JOB RETRAINING

TIME FRAME

- RAPID MARKET PENETRATION FOR IC DESIGN NOW UNDERWAY
- ACCELERATING GROWTH THROUGHOUT DECADE IN OTHER APPLICATIONS
- CAD WILL GRADUALLY INCORPORATE MANUFACTURING ENGINEERING FUNCTIONS

Implications Relevant to California's Economy

- Much larger variety will be supplied in computer products--especially consumer electronics.
- Increased demand for midlevel and senior design engineers.

Venture Capitalists' Comments:

- Of the 19 areas reviewed here, CAD was seen as the most exciting by the majority of venture capital respondents

Exhibit 9

INDUSTRIAL ROBOTS

- REPROGRAMMABLE, AUTOMATED MACHINES THAT REPLACE HUMANS IN MANUFACTURING
- SIMPLE, LIMITED SEQUENCE ARMS TO COMPLEX COMPUTER-CONTROLLED, MULTIAXIS SYSTEMS

ADVANTAGES

- REDUCE MANUFACTURING COST
  - LABOR PRODUCTIVITY
  - EQUIPMENT UTILIZATION
  - SCRAP & WASTE
- ELIMINATE HAZARDOUS JOBS

DISADVANTAGES

- CREATE JOB DISPLACEMENT AND RETRAINING PROBLEMS
- LACK HUMAN INTELLIGENCE
- INCREASE FIXED COST

APPLICATIONS

- WELDING
- PAINT SPRAYING
- DIE CASTING/FORGING
- MATERIAL HANDLING
- ASSEMBLY

MARKETS

- ELECTRONICS
- AUTOMOTIVE
- AEROSPACE
- INDUSTRIAL EQUIPMENT/MACHINERY

BARRIERS TO COMMERCIALIZATION

TECHNICAL

- SENSORY FEEDBACK
- ADAPTABILITY/MOBILITY
- SYSTEMS INTEGRATION (e.g. PARTS FEEDERS)

NON-TECHNICAL

- UNION OPPOSITION
- SHORT TERM PAYBACK FOCUS
- SKILL SHORTAGE

TIME FRAME

- ROBOT INSTALLATIONS (CURRENT TECHNOLOGY) GROWING IN EXCESS OF 30% PER YEAR
- DEVELOPMENT OF "SMART" ROBOT TECHNOLOGY PROCEEDING AT ACCELERATED PACE
- SOME "SMART" ROBOTS IN PLACE (ASSEMBLY) BY END OF DECADE

Implications Relevant to California's Economy

- California will be a major supplier of robots.
- Some of California's industries will be among the first to robotize (aerospace and electronics).

Venture Capitalists' Comments:

- This product depends on software, which is not very attractive as a venture capital opportunity. However, both domestic and foreign robots will be major forces in California throughout the decade. California will supply much of the design and development talent needed in this field.

Exhibit 10

FACTORY AUTOMATION

- APPLICATION OF MICROELECTRONICS TECHNOLOGY TO INCREASE MANUFACTURING PRODUCTIVITY
- LINKAGE OF CAD, CAM, AND FACTORY MANAGEMENT SYSTEMS

ADVANTAGES

- INCREASES OUTPUT/MAN-HOUR
- ELIMINATES HAZARDOUS/TEDIOUS JOBS
- STRENGTHENS U.S. COMPETITIVENESS
- INCREASES PRODUCT FLEXIBILITY
- IMPROVES PRODUCT QUALITY

DISADVANTAGES

- JOB DISLOCATION/TRAINING
- FUTURE LABOR SURPLUS?

APPLICATIONS

- DISCRETE PARTS MANUFACTURE
- CONTINUOUS PRODUCTION PROCESSES

MARKETS

- ALL MANUFACTURERS EXCEPT VERY LOW VOLUME, SPECIALTY SHOPS

BARRIERS TO COMMERCIALIZATION

TECHNICAL

- SOFTWARE DESIGN/COMPATIBILITY
- INTEGRATED, COMMON DATABASES

NON-TECHNICAL

- CAPITAL INVESTMENT REQUIREMENTS
- NEW JOB SKILLS (UNION RESISTANCE)
- NEED TO RESTRUCTURE MANUFACTURING

TIME FRAME

- IMPLEMENTATION CURRENTLY DOMINATED BY AUTOMATION OF SPECIFIC FUNCTIONS
- MAJOR SUPPLIERS NOW TOOLING UP FOR INTEGRATED SYSTEMS APPLICATIONS
- TRUE "FACTORY-OF-THE-FUTURE" RARE BEFORE 1990s

Implications Relevant to California's Economy

- More assembly jobs in the 1980s but a potentially rapid decline in assembly jobs in the 1990s and beyond.
- Restructuring of more production operations to 24 hours (especially larger operations).
- More focus on quality control will mean less failure in the field, which means less demand for service and repair.

Venture Capitalists' Comments:

- This technology is emerging, but it is not easily characterized in a form attractive to venture capital investment. Such automation will be accomplished in increments based on changing practices between automated machine producers and major production facility operators.

Exhibit 11

ARTIFICIAL INTELLIGENCE — EXPERT SYSTEMS

- COMPUTER SOFTWARE THAT REPRESENTS EXPERT, PROBLEM-SOLVING KNOWLEDGE THAT CAN BE EASILY ACCESSED BY NON-EXPERTS
- TWO ELEMENTS — THE KNOWLEDGE ITSELF AND THE INFERENCE PROCEDURES (RULES OF THUMB)

ADVANTAGES

- EXTENDS SPECIALIZED EXPERTISE
- TIME/COST SAVINGS IN TRADITIONAL DECISION-MAKING

DISADVANTAGES

- CONCLUSIONS MAY BE INVALID
- LIMITED TO VERY SPECIFIC PROBLEMS

APPLICATIONS

- GEOLOGICAL EXPLORATION
- COMPUTER FAULT DIAGNOSIS
- MEDICAL DIAGNOSTICS
- TEACHING SYSTEMS
- COMPLEX SYSTEM DESIGN

MARKETS

- MINERAL/OIL EXPLORATION
- TRAINING AND MAINTENANCE SERVICES
- FACTORY AUTOMATION
- DOCTORS, LAWYERS
- VLSI DESIGN
- RESEARCH
- MILITARY

BARRIERS TO COMMERCIALIZATION

TECHNICAL

- CONSTRUCTION OF DATABASE/RULES
- NATURAL LANGUAGE AVAILABILITY
- EFFICIENT SEARCH STRATEGIES
- HUMAN THINKING PROCESS NOT UNDERSTOOD

NON-TECHNICAL

- SHORTAGE OF COMPUTER SCIENTISTS
- USER RELUCTANCE

TIME FRAME

- RESEARCH MOVING OUT OF UNIVERSITIES INTO INDUSTRY — STILL DEVELOPMENTAL
- FIRST COMMERCIAL MARKETS WILL EMERGE IN 5-10 YEARS

Implications Relevant to California's Economy

- Increasing proportion of expertise built into work stations and automated service units (e.g., bank teller machines).
- Automated paraprofessional systems (1990's) for legal, medical, accounting, etc.
- Redesign of most professional jobs.
- More "self-help" systems from medical, to auto repair, to tax preparation.

Venture Capitalists' Comments:

- This technology will have great impact on California in the late 1980s and beyond. At the present time it is not an opportunity generally attractive to venture capital investment. The future impact will be to displace large numbers of less skilled or semiskilled labor.

Exhibit 12

HEAT PUMPS

- MOVE THERMAL ENERGY FROM LOW TEMPERATURE SOURCE TO HIGH TEMPERATURE DEMAND

ADVANTAGES

- EXTRACT USEFUL ENERGY FROM WASTE HEAT SOURCES
- ENERGY MULTIPLICATION OF 2 OR 3
- PRODUCE COLD AS A BY-PRODUCT

DISADVANTAGES

- HIGH FIRST COST
- USUALLY MORE COMPLEX MAINTENANCE
- NOISE

APPLICATIONS

- HEATING ANY AIR OR WATER MEDIUM
- ADVANCED APPLIANCE CONCEPTS (AIR CONDITIONER AND WATER HEATER COMBINED)

MARKETS

- BUILDING SPACE HEATING
- WATER HEATING
- INDUSTRIAL DRYING

BARRIERS TO COMMERCIALIZATION

TECHNICAL

- EXTEND LIFE BEYOND CURRENT 5-10 YEAR

NON-TECHNICAL

- LACK OF TESTING PROCEDURE
- STATE/LOCAL REGULATIONS

TIME FRAME

CONTINUOUS EXPANSION OF MARKET

Implications Relevant to California's Economy

- Increased relative attractiveness/advantage of mild climates as living/office sites.
- Increased relative demand for electricity in heating

Venture Capitalists' Comments:

- This technology will be attractive only as the efficiency of these devices increases.

Exhibit 13

PHOTOVOLTAIC ENERGY CONVERSION

- SOLID STATE DEVICES WHICH DIRECTLY CONVERT SUNLIGHT INTO ELECTRICITY

ADVANTAGES

- SILENT, NO MOVING PARTS
- NO COOLING REQUIRED
- MODULAR SIZE

DISADVANTAGES

- HIGH COST
- LARGE SUNNY AREAS REQUIRED

APPLICATIONS

- ISOLATED POWER NEEDS WITH BATTERIES
- GRID-CONNECTED FOR UTILITY POWER

MARKETS

- CONSUMER ELECTRONICS
- COMMUNICATION RELAYS
- CATHODIC PROTECTION

BARRIERS TO COMMERCIALIZATION

TECHNICAL

- LOW CONVERSION EFFICIENCY
- REDUCTION IN OUTPUT OVER TIME

NON-TECHNICAL

- JAPANESE
- LARGE INVESTMENT REQUIRED
- HIGH FIRST COST

TIME FRAME

1980'S ISOLATED POWER SUPPLIES
1990'S UTILITY POWER

Implications Relevant to California's Economy

- Probable decline of California's current photovoltaic business.
- Potential for California as a Japanese base.

Venture Capitalists' Comments:

- This technology has been dominated in the U.S. by NASA/military needs and investments. There is no clear new general opportunity in this area for U.S. firms in the face of current foreign competition.

Exhibit 14

COGENERATION

- SIMULTANEOUS PRODUCTION OF USEFUL HEAT AND ELECTRICAL POWER

ADVANTAGES

- MORE USEFUL ENERGY

DISADVANTAGES

- HIGHER FIRST COST
- SITING DIFFICULTIES
- COMPLEX EQUIPMENT
- MATCHING HEAT LOAD AND POWER OUTPUT

APPLICATIONS

- BOILER/STEAM TURBINE
- IC ENGINE/HEAT
- FUEL CELLS

MARKETS

- HEAVY OIL RECOVERY
- COMMERCIAL BUILDINGS

BARRIERS TO COMMERCIALIZATION

TECHNICAL

- RELIABILITY
- EMISSION CONTROL

NON-TECHNICAL

- IDENTIFYING APPLICATIONS
- BUILDING CODES AND PRACTICES
- HIGH FIRST COST
- UTILITY REGULATIONS

TIME FRAME

CONTINUOUS EXPANSION OF MARKET

Implications Relevant to California's Economy

- Some restructuring of public utilities' role from sole source of electricity to load manager between sources and users.

Venture Capitalists' Comments:

- This was not generally seen as a venture capital opportunity. Moreover, the rate of commercialization was judged to be relatively slow, unless there is another major oil price increase.

Exhibit 15

ENERGY MANAGEMENT AND CONTROL SYSTEMS

- COMPUTER CONTROL OF ENERGY CONSUMING SYSTEMS AND DEVICES

ADVANTAGES

- SAVE ENERGY
- FAVORABLE ECONOMICS
- TAKE ADVANTAGE OF ELECTRONIC DEVELOPMENTS

DISADVANTAGES

- HIGHER FIRST COST
- MORE COMPLEX PRODUCTS

APPLICATIONS

- ANY COMBUSTION OR ELECTRICAL CONSUMING PROCESS

MARKETS

- COMMERCIAL BUILDINGS
- INDUSTRIAL PROCESSES
- AUTOMOBILES
- APPLIANCES

BARRIERS TO COMMERCIALIZATION

TECHNICAL

- DEVELOPMENT OF LOW-COST SENSORS

NON-TECHNICAL

- CONSUMER PRODUCTS TOO SENSITIVE TO FIRST COST
- IDENTIFYING FAVORABLE MARKET NICHES
- TRAINING MAINTENANCE PERSONNEL

TIME FRAME

- BASIC AND COMMERCIAL CONTROLLERS AVAILABLE TODAY
- RAPID BROADENING OF COMMERCIALIZATION IN EARLY 1980's

Implications Relevant to California's Economy

- Dramatic improvements in energy conservation increases.

Venture Capitalists' Comments:

- This was viewed as an exciting area with a reasonably wide range of opportunities; however, several specific major suppliers were noted to have well-established programs in this area.

Exhibit 16

METALLIC GLASSES

$Fe_{80}B_{20}$, $Pd_{80}Si_{20}$, $Cu_{57}Zr_{43}$, TRANSITION METAL + B, C, N, Si, OR P

- RAPIDLY QUENCHED METALLIC ALLOYS WITH NO LONG-RANGE CRYSTALLINE ORDER

ADVANTAGES

- HIGH STRENGTH — HIGH STIFFNESS
- GOOD FRACTURE TOUGHNESS
- STRENGTH ISOTROPIC
- CORROSION RESISTANCE
- EASE OF MAGNETIZATION

DISADVANTAGES

- DETERIORATE AT HIGH TEMPERATURE
- THIN CROSS SECTIONS NECESSARY

APPLICATIONS

- BRAZING ALLOYS
- RECORDING HEADS
- TRANSFORMER CORES
- PRESSURE VESSELS
- CABLE SHEATHING
- RAZOR BLADES/SCALPELS

MARKETS

- ELECTRONICS
- METAL FABRICATION
- ELECTRIC UTILITIES
- AEROSPACE
- MEDICAL

BARRIERS TO COMMERCIALIZATION

TECHNICAL

- AVAILABLE ONLY IN THIN CROSS-SECTIONS (WIRES, FOILS, TUBES, ETC.)
- UNCONVENTIONAL FABRICATION

NON-TECHNICAL

- ENGINEERING FAMILIARITY
- USER CONSERVATISM

TIME FRAME

- BRAZING ALLOYS: NOW IN USE
- TRANSFORMER CORES/MOTORS: MID TO LATE 1980s

Exhibit 17

HIGH-TEMPERATURE STRUCTURAL CERAMICS (SiC, Si_3N_4)

- SUBSTITUTE FOR METALS IN SEVERE ENVIRONMENTS
- RESISTANT TO (1) OXIDATION
  (2) HOT CORROSION
  (3) EROSION

ADVANTAGES

- HIGH STIFFNESS
- HIGH STRENGTH
- LOW DENSITY
- GOOD THERMAL SHOCK RESISTANCE
- HARD

DISADVANTAGES

- BRITTLE (FAILURE CATASTROPHIC)
- EXPENSIVE FABRICATION

APPLICATIONS

- HEAT ENGINES
- HEAT EXCHANGERS
- BEARINGS
- CUTTING TOOLS

MARKETS

- AUTOMOBILES/TRUCKS
- METAL MACHINING
- UTILITIES

BARRIERS TO COMMERCIALIZATION

TECHNICAL

- FABRICATION
- PROOF TESTING (QUALITY ASSURANCE)

NON-TECHNICAL

- ENGINEERING FAMILIARITY
- SAFETY PROCEDURES

TIME FRAME

- CUTTING TOOLS: NOW BEING INTRODUCED
- HEAT ENGINES: MID-1980s

Exhibit 18

SOLID ELECTROLYTES $CaO\text{-}ZrO_2$, $\beta\text{-}Al_2O_3$

- SOLID MATERIALS THAT SUPPORT IONIC CONDUCTION
- CONDUCTION MAY VARY WITH CONCENTRATION OF SOME EXTERNAL SPECIES (e.g., O_2)

ADVANTAGES

- SENSORS: SOLID STATE, VERY SENSITIVE
- BATTERIES: HIGH SPECIFIC POWER
  CHEAP MATERIALS

DISADVANTAGES

- WON'T WORK AT ROOM TEMPERATURE
- MATERIALS PROBLEMS

APPLICATIONS

- OXYGEN SENSORS ($CaO\text{-}ZrO_2$)
- BATTERIES (Na-S USES
  $\beta\text{-}Al_2O_3$ ELECTROLYTE)

MARKETS

- AUTOMOBILES
- TRANSPORTATION, ELECTRIC UTILITIES

BARRIERS TO COMMERCIALIZATION

TECHNICAL

- RELIABILITY (BATTERY ELECTROLYTE)
- FABRICATION PROBLEMS
- SENSITIVITY

NON-TECHNICAL

- LACK OF USER FAMILIARITY

TIME FRAME

- OXYGEN SENSORS: NOW IN USE IN AUTOS AND STEEL INDUSTRY
- Na/S BATTERIES: LOAD LEVELING — MID TO LATE 1980s
  ELECTRIC AUTOS — LATE 1980s

Implications Relevant to California's Economy

- Opens yet a third area (after electronics and biotechnology) as a potential source of major new industries.
- Has clear defense related application and hence will be devloped in the defense buildup.

Venture Capitalists' Comments:

- This new materials technology in general is not yet developed to the point where it is broadly understood, therefore, commercial potential is not clearly obvious to todays venture analysts. However, new venture proposals in this field are beginning to be brought forward.

Exhibit 19

IRRADIATION

- EXPOSURE OF FOOD PRODUCTS TO HIGH-ENERGY RADIATION FOR PURPOSES OF DISINFESTATION AND PRESERVATION

ADVANTAGES

- NO TOXIC RESIDUES
- ENERGY SPARING: ECONOMICAL
- PERMITS ECONOMICAL PACKAGING
- MINIMIZES FOOD LOSSES

DISADVANTAGES

- PUBLIC APPREHENSION
- REGULATORY COMPLIANCE

APPLICATIONS

- DISINFESTATION OF FRESH FRUITS & VEGETABLES
- ASEPTIC PACKAGING OF FOODS
- PRESERVATION OF FOOD PRODUCTS

MARKETS

- PRODUCE; INTERSTATE SHIPPING
- FOOD PROCESSING

BARRIERS TO COMMERCIALIZATION

TECHNICAL

- DOSAGE/RANGEFINDING
- RAPID MONITORING

NON-TECHNICAL

- REGULATORY APPROVAL (FDA/USDA)
- LICENSING FOR SOURCES
- LOGISTICS/SYSTEMS

TIME FRAME

1982

Implications relevant to California's Economy

- Restructuring and rejuvenation of California's canning industry.
- Preservation of profitable exportability of California fresh fruit and vegetables in the face of pest infestations.

Venture Capitalists' Comments:

- This technology has not yet resulted in any clear new venture opportunities reported to us. The technology may be commercialized by existing larger agricultural and food processing organizations.

Exhibit 20

TISSUE CULTURE/MICROPROPAGATION

- PROPAGATION OF SPECIFIC PLANT OR ANIMAL CELLS IN A CULTURE MEDIUM SEPARATE FROM THE NORMAL GROWING ENVIRONMENT

ADVANTAGES

- MORE RAPID GENETIC MANIPULATION ACROSS GENERATIONS
- RAPID DEPLOYMENT OF NEW ACREAGE
- PRESERVING GERM PLASM LINES

DISADVANTAGES

- LABOR INTENSIVE COMPARED WITH SEED PROPAGATION

APPLICATIONS

- FRUIT & VEGETABLE GENETICS
- RAPID REFORESTATION
- USE OF PLANT ORGANS & BY-PRODUCTS

MARKETS

- FRUIT & VEGETABLE FARMING
- FORESTRY
- PLANT BY-PRODUCTS

BARRIERS TO COMMERCIALIZATION

TECHNICAL

- TECHNICAL HUMAN RESOURCES
- LARGE SCALE EXPERIENCE
- SOME BASIC R&D e.g. PLANT DNA SEQUENCING

NON-TECHNICAL

- LIMITS OF PATENT PROTECTION
- CAPITALIZATION FOR FACILITIES

TIME FRAME

MASS MICROPROPAGATION	1984-1988
TISSUE CULTURE, ORGANS	1988-1992

Implications Relevant to California's Economy

- Research and development focus in 1980s will be on high-value crops--favors California agriculture over the grain belt.

Venture Capitalists' Comments:

- The time frame for this technolgy to commercialization is still long enough that few venture capitol deals have been proposed to date.

Exhibit 21

RECOMBINANT DNA

- TRANSFER OF GENE BASED TRAITS FROM ONE PLANT OR ANIMAL TO ANOTHER

ADVANTAGES

- INCREASED YIELDS
- REDUCED PROCESS COSTS
- DECREASED PETROLEUM DEPENDENCE

DISADVANTAGES

- PUBLIC FEARS OF ECOLOGICAL CONSEQUENCES
- LONG TERM OUTLOOK

APPLICATIONS

- MEDICINE
- CHEMICALS
- FOOD/AGRICULTURE
- ENERGY

MARKETS

- DIAGNOSTICS
- BIOCATALYSTS
- IMPROVED PLANT SPECIES
- ENHANCED OIL RECOVERY

BARRIERS TO COMMERCIALIZATION

TECHNICAL

- COMPLEX, INTERDISCIPLINARY TECHNOLOGY

NON-TECHNICAL

- SHORTAGE OF TRAINED TECHNICIANS
- GOVERNMENT REGULATION (NIH, FDA)
- PATENT PROTECTION
- ETHICAL/SOCIAL ISSUES

TIME FRAME

- MEDICAL APPLICATION 1983-1990
- FOOD/AGRICULTURE/ENERGY 1986-2000

Implications Relevant to California's Economy

- California has the potential to dominate the development of this industry.

Venture Capitalists' Comments:

- This is expected to yield a large number of new venture opportunities in the later part of the 1980s as the basic technology becomes proven.

Technological Interactions

Previous major technological changes have typically come into public use singularly and in series, for example, the steam engine, the jet plane, atomic power, and the computer. Today the rate and breadth of technological change is so great that the interactions between new and old technologies, or the combinations of new technologies, have even greater implications for society than do individual technologies. Table 3 shows how some of the technologies reviewed in the report interact in different applications. The purpose of this table is to show what we believe is increasingly the case, i.e., that today's new technologies have further reaching, more complex implications that ever before.

Table 3

INTERACTIONS AMONG NEW TECHNOLOGIES IN VARIOUS APPLICATIONS

	Applications				
Technology	Automotive (2700 LB Fairlane with 50 MPG)	Sporting Goods	Factory Automation	Building Energy Management and Control Systems	Defense Aerospace
Fiber-reinforced composites	X	X			X
Electronic controls systems	X		X	X	X
Ceramic components	X			X	X
CAD design	X	X	X	X	X
CAM production	X		X	X	X

Conclusions About the Directions of New Technology

The net conclusion that we draw from our technology assessment is that California is an "emerging industrial-information economy." Through new technology, the proportion of effort and investment in the amount of information generated and used in California business, industry, and agriculture is rising rapidly. Moveover, one of California's largest growth sectors is the production and application of new technology. As the northeast is the nation's "foundry" and the midwest its "breadbasket," California is its "R&D" center.

This fact has major implications for approaches to monitoring economic health. Table 4 compares useful economic indicators in an industrial society vis-a-vis an industrial-information economy.

Table 4

ECONOMIC INDICATORS

Indicators in an Industrial Society	Indicators in an Industrial Information Economy
. The rate of production of physical goods.	. The rate of turnover in the inventory of technology.
. The rate of employment within industries.	. The rate of employment turnover between industries.

III IMPACTS OF NEW TECHNOLOGIES

California has long been oriented toward new technologies. Nineteenth century California was largely created by the success of railroad and new mining technologies. Early 20th century California growth was based on new automobile, motion picture, and water supply technologies. In the middle of the 20th century, California growth was largely driven by employment in the new aerospace and defense electronics industries.

By the 1950s California had moved from a user to a developer of new technologies. California scientists developed the first electron tube, the first cyclotron, and finally the first integrated circuit semiconductor. Several California universities, particularly Stanford University and UC-Berkeley, achieved worldwide recognition in many scientific fields.

Given this history, the increasing orientation of California industry toward high-technology products should not be surprising. What is likely to be surprising is the impact of these products on workers and consumers. The coming impacts of technology will be on commercial users more than on the manufacturers of new technologies. These user impacts will affect a wide range of occupations, changing both the type of work and the training required. While the technologies will help solve many existing state problems such as water and energy shortages, their occupational impacts will tend to create new economic and social problems for the state. Because technical impacts will be so complex, they will be reviewed in four parts: direct employment, user industry, occupational, and public sector.

Direct Employment Impacts

Over 700,000 California workers (about 7 percent of its workforce) are already in technically oriented industries--primarily computer, electronics, and aircraft. More importantly, these industries represent about 18 percent of the state's industrial employment. Between 1972 and 1979, employment in these technical industries increased by more than 50 percent.

Employment growth in California's technically oriented industries is likely to be both somewhat slower and changing in character during the 1980s. Unexpected technically based employment growth during the 1970s was principally in electronics manufacture; in the 1980s changes in employment resulting from technology is likely to be more oriented toward electronics software, non-electronics, and electronics applications industries. Table 5 reviews projected growth by industry.

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Table 5

DIRECT EMPLOYMENT IMPACTS BY INDUSTRY

Industry	Number of workers: 1979 Employment	Number of workers: Increase by 1990	Timing of the Change in Employment	Remarks on Employment Impacts
Drugs SIC 283	16,500	5-15,000	Late-80s	Very high-value, low-volume, low-employment products. Genetic engineering impact likely to have fairly low direct employment impacts, but great impacts in use. Housing problems already limiting early California techical lead.
Agricultural Chemicals SIC 287	5,300	5-15,000	Mid-80s	Genetic engineering and insect hormones likely to have great commercial impact but employment likely to be fairly low.
Computers SIC 357	93,000	20-50,000	Early 80s	California losing advantage as manufacturing locale. Employment shifting to design and software. Memory manufacture shifting to optical systems. Market lead over Japan likely to continue throughout 1980's.
Communication Equipment SIC 366	123,400	20-40,000	Early 80s	Shift to optical and satellite systems but only modest employment impact.

*SIC - Standard Industrial Classification

DIRECT EMPLOYMENT IMPACTS BY INDUSTRY (Concluded)

Industry	Number of Workers 1979 Employment	Number of Workers Increase by 1990	Timing of the Change in Employment	Remarks on Employment Impacts
Electronic Components SIC 367	114,600	20-40,000	Early 80s	Production shifting away from California and becoming more automated. Further growth depends on applications requirements catching up with capabilities.
Aircraft SIC 372	141,300	20-50,000	Late 80s	Decline from L-1011 cancellation will ultimately be more than compensated for by growing military construction.
Guided Missiles SIC 376	51,500	20-40,000	Mid-80s	Major technical advances are shifting military demand to this sector. Very high employment growth is likely.
Computer Business Services, Software, Computer-Based Information Services		40-100,000	Throughout 80s	Continued very high growth independent from computer manufacturers.

User Industry Impacts

In the past, new technologies have tended on the whole to create more jobs than they displaced. This has been true because the increase in capability and decline in costs resulting from new technology have created new product and service categories and have brought costs of many existing products within reach of the average consumer. The degree to which technology increases or decreases the total number of jobs depends on the balance between the employment loss from producing more output per worker and the employment gain from new markets created by lower costs and new capabilities. For example, a single California manufacturer can now produce logic and memory devices equivalent to the world's output in 1960, but completely new applications have appeared to increase demand as fast or faster than supply. The net result is that, while technology has radically improved worker productivity, it has also drastically reduced costs. Therefore, output has increased by orders of magnitude, and employment has roughly doubled.

New technology can also give local industry a competitive edge. Such a competitive advantage can mean growing local employment, even though employment in the industry as a whole might decline. California has already taken advantage of such a situation by doubling its employment in electronic components during the 1970s, even though total national employment in that industry stayed roughly constant.

In light of these two forces (substitution of new jobs for old and comparative technological advantage) the employment impacts of new technology on important California industries may be summarized as follows:

Agriculture

Agriculture is still California's largest industry with more than 500,000 workers. However, this industry faces a number of severe threats in the 1980s. Much of California's agricultural success has been the result of cheap water (heavily subsidized), cheap labor, cheap energy, and relative lack of

contamination by insect pests. All of these advantages will tend to decline over the next decade. Moreover, international competition in agriculture is likely to increase.

Many new technologies could help to maintain California's agricultural output and employment in the face of these threats, but the realization of this technical potential is far from certain. Technologies have been invented that conserve water, energy, and labor and deal with insect pests, but their use is largely a function of barriers and incentives in public policy.

Current water policy is the most obvious example of a barrier preventing widespread commercial use of water-conserving technologies. California has had cheap water because:

- Millions of savers were willing to buy 3, 4, or 5 percent bonds to build California dams
- Non-Californian taxpayers were willing to subsidize California's water systems
- Urban California taxpayers were willing to subsidize water systems for California agriculture.

However, the public will to preserve these past water subsidies is dying: savers are demanding higher interest rates, the federal government is cutting back on new projects, and urban California voters are challenging water projects such as the Peripheral Canal. The era of increasing quantities of publicly subsidized water is ending, but agricultural water price policy does not yet fully reflect this.

Water-saving technologies will be developed and commercially applied (thereby creating a new agricultural industry) when it is clear that water prices will rise to a level where it will pay farmers to conserve water. New kinds of crops, new cultivation techniques, drip irrigation, improved control systems, and reverse osmosis systems could save enormous amounts of water. However these water-saving technologies will be neither developed nor used as long as most agricultural water continues to be priced below the level at which increased conservation will pay.

The changing cost of agricultural labor, on the other hand, is already a strong incentive for new technology deployment. Under the pressures of an increased cost of living and unionization, agricultural wages are increasing faster than agricultural prices and productivity. Competition from Mexico is increasing in the markets for many fruits and vegetables, thereby holding down domestic prices. Labor-saving technology is the obvious way to pay higher wages, yet keep total labor costs down. Public policy proposals to discourage or withhold support for the development of labor-saving machinery guarantee either low wages (i.e., strong incentives to use illegal alien labor) or decline of the labor-intensive portion of California's agricultural industry.

The Mediterranean fruit fly problem could be just the beginning of a new class of pest control problems. With increased travel opportunities and a populace unwilling to cooperate in controlling the spread of agricultural pests, California is likely to lose its relative isolation from infestation by alien pests. New technologies such as use of insect hormones and new insect diseases could help solve this problem, but faster development of such technologies is vital.

A technology new to the United States, irradiation, is available to disinfect produce. Moreover, irradiation can cut food processing costs, because it can be used to sterilize; it saves energy, requires less labor, and avoids the risks of chemical contamination. This technology uses radiation to both decontaminate and help preserve produce. Food preserving use of radiation was developed by the U.S. Army and has been used in Europe for several years. Although the technology has been approved recently by the Food and Drug Administration (FDA), its use may generate public controversy. In the face of agricultural pests, however, the state may have to choose among the loss of its fresh fruit industry, the real dangers of ethylene dibromide, or the use of irradiation. Moreover, irradiation may offer the means to rejuvenate the state's canning industry by allowing food to be sterilized without the large amounts of heat energy that must be used today.

Manufacturing

The 1980s will see the start of a general application of the automated factory technologies; computer-assisted design, computer-assisted manufacture, robots, and intelligent management information systems. Each set of technologies will be applied at a different rate and in different combinations in each industry. On the whole, these new technologies are unlikely significantly to increase or decrease total manufacturing employment in the 1980s, however, there will probably be a significant decline in manufacturing employment (both assembly workers and mid-level managers and supervisors) in the 1990s. The rate of displacement will vary a great deal by industry, and there may be significant movement from one type of manufacturing to another in the 1980s. For example, automobile manufacturing employment might decline (or simply stay at its present low), while office equipment manufacturing employment may increase.

The result of automation is that employment will likely decline below its recent levels in more mature industries where the market will not grow much even with price reductions or new products. Such a decline would be likely in such basic products as basic foods, paper, chemicals, automobiles, tires, and major home appliances.

Employment increases above recent growth levels will be most likely in new products, such as electronic consumer goods and new business products. California employment might increase even if national employment decreases in some of these industries, if California can gain a technical advantage in new production processes (for example, application of automation to automobiles or of irradiation to canning).

Transportation

New materials and electronic control technologies are likely to improve fuel efficiency dramatically in all modes of transportation. This increased

fuel efficiency will help prevent cost increases and the declines in demand that would otherwise occur. This impact will be felt most strongly in air transportation, which will resume its growth as more fuel-efficient aircraft come into use.

Communication

In the communications industry, high growth is likely to be centered on the installation and maintenance of high-power satellite and broadband cable communication systems. Employment in the industry could grow by 40,000 to 60,000. Also within this sector, a new service sector will emerge including "information utilities" such as Lockheed's Dialog and "entertainment utilities" such as video recording rental services.

Trade

The retail and wholesale trade industry is most likely to be affected by new electronic shopping systems. Price comparisons and merchandise shipping by computer-controlled video systems are the natural outgrowth of cable T.V., personal computers, and the electronic yellow pages. This is likely to encourage another level of retail establishment; the electronic "super store," with price comparisons, merchandise display, ordering, and payment all handled electronically. Super stores would be the electronic version of catalogue stores and their costs could be well below today's competition. Traditional stores will have to emphasize personalized service and customer assistance even more than currently.

Overall employment in the trade industry is likely to grow somewhat more slowly and competition is likely to intensify. The number of retail clerks in any given existing retail operaton will likely decline; however, this may be offset by an increase in the number and types of retail products and outlets.

Finance, Insurance, and Real Estate

This industry is already highly automated, but employment has continued to increase as automation has made new services possible. This pattern is likely to continue as automation enables more personalized financial, insurance, and real estate services. However, the next wave of automation is likely to be so strong that aggregate employment growth will probably be slower in this industry in the 1980s.

Services

Growth in this sector will tend to be concentrated in information services, software, business services, and video entertainment. California is an international center for many parts of these industries, whose growth potential is spectacular. Of particular importance to California are the enormous requirements for entertainment to fill the new video channels (satellite, home video players). Electronically created animation is one new industry that ultimately will help fill this gap. Other new entertainment products may include randomly accessible video stories by which each viewer can direct the plot in different directions--the ultimate "Dream Machine." Motion picture employment could easily double in the decade, and the other electronic services (i.e., electronic publishing) are likely to grow even more. Many of the businesses that will serve this market are likely to be very small, independent operations. This is the key growth sector for small business.

Government

Government employment is likely to be affected by more automation of clerical tasks and by private-sector competition for some government services. Competition will be most severe for the Post Office, where

business mail will simply become too costly compared to electronic communication. As a result, government employment is likely to continue to grow more slowly than the economy as a whole.

Occupational Impacts

The impact of new technologies on the demise of old occupations and creation of new ones is likely to be dramatic. During the coming decade, many of today's largest occupations will decline or experience wholesale change. These include some of the following:

- Bank tellers: Replaced by automated tellers and declining number of personal visits to banks per client. Moreover expert systems may allow integration of Teller and first line supervisor responsibilities.
- Secretaries: This job will split into two new roles: word processor operators and office managers/professional assistants.
- Stenographers: Largely disappearing (direct voice driven automated dictation is probable in the early 1990's).
- Assembly Workers: Increasingly replaced by robots.
- Key Punch Operators: Replaced by OCR and other electronic systems.
- Retail Sales Clerks: Replaced by automated buying systems.

These impacts will fall particularly hard on less educated female workers. High level occupations will also be affected:

- Technical Personnel: Faster technical obsolescence.
- Managers: Computer literacy becoming mandatory.

Compared to current California Economic Development Department occupational projections for 1985, new technologies will have the following impacts:

- Professional-Technical: Much more growth

- Managers: More growth
- Sales Workers: About as projected
- Clerical Workers: Less than projected
- Craft Workers: About as projected
- Operatives: About as projected
- Service Workers: More growth than projected.

Public Sector Impacts

Beyond their impacts on employment, the new technologies will both help to solve many current social and economic problems and create some new problems. The new technologies will help to solve the problems of the industrial era, such as shortages of energy and water shortages, chemical pollution, and congestion. The new problems are the problems of the information era: new divisions between the technical elite and the technically illiterate, labor shortages in the midst of growing unemployment, and (California's special), the bitter debate over housing and growth controls. These issues are summarized in Tables 6 to 8.

PROBLEMS OF THE INDUSTRIAL ERA

PROBLEMS	TECHNICAL SOLUTIONS
ENERGY	PHOTOVOLTAICS, COGENERATION
WATER	NEW CROPS, REVERSE OSMOSIS
TRANSPORTATION	DECENTRALIZED WORK PLACES

POLITICAL/LEGAL BARRIERS TO TECHNICAL SOLUTIONS

PROBLEM	TECHNICAL SOLUTION	BARRIERS
ENERGY	WIND ENERGY	MARKET PRICING UTILITY REGULATION
WATER	DROUGHT RESISTANT CROPS	MARKET PRICING OWNERSHIP OF UNDERGROUND WATER CROP PATENTS
TRANSPORTATION	DECENTRALIZED WORK SITES "TELECOMMUTING"	FRINGE BENEFITS, INSURANCE, ZONING, FINANCE, UNEMPLOYMENT INSURANCE, CABLE — TV REGULATIONS

PROBLEMS OF THE INFORMATION ERA

PROBLEM	SOLUTIONS
HOUSING SHORTAGES	ZONING, FINANCIAL REFORM
TRAINED MANPOWER SHORTAGES	IMPROVED AND EXPANDED EDUCATION
DECLINE OF BLUE-COLLAR INDUSTRY	RETRAINING
ROLE OF HISPANICS	EDUCATION, EMPLOYER FLEXIBILITY, IMMIGRATION CONTROLS, AID TO MEXICO
INCREASED SPRAWL	IMPROVED LAND-USE PLANNING

Proper government policies can encourage technical solutions to problems, as exemplified by the evident success of technical solutions to California's energy problems. The California economy grew almost 50 percent since 1970, but industrial energy use declined between 1970 and 1978. California is a leader in wind energy, geothermal energy, solar energy, and energy conservation. However, these technical solutions were not used until improved price incentives and other regulatory improvements were implemented in the mid to late 1970's. A wide range of new energy conservation and production technologies will continue to come into use during the 1980s.

As previously discussed, similar needs and technical potentials exist to solve the agricultural problems of water, pests, and high labor costs. The missing ingredients are inadequate price incentives and support for basic research.

Transportation

The transportation industry is facing a situation similar to energy and agriculture. Existing facilities are overburdened, but many feel that new facilities would be too costly both economically and environmentally. The technical solutions are obvious: on the one hand, new communications media can encourage less commuting, less shopping travel, and dispersal of population; on the other hand, new materials, combustion, and control technology can greatly improve the efficiency of both public and private transport. Enormous but unrecognized potential exists to reduce the demand for transportation. State telecommunications policy and regulation of small dispersed businesses could be used to encourage substituting communications for highways and traffic. Traffic control and information systems also have potential to help solve transportation problems. These technical solutions may prove far less expensive than either highway construction or mass transit, and therefore should be analyzed in state planning.

Education

Perhaps the most serious problem of the new "information era" is the conflict between the demands of an increasingly technically oriented industry and the current pattern of reductions in state support for education. These cutbacks are taking place in the face of growing educational challenges. Well over 25 percent of the elementary enrollment is ethnic in character with both language and other educational problems. This large and growing group of students must be brought up to the new standards of technical literacy, otherwise there will be drastic social and economic consequences, and a potentially alienated ethnic group that will present continuing high unemployment problems.

In addition to the general problem of financing education to meet this need there are structural weaknesses which may prove increasingly detrimental to the system. California's educational system, bound by current rules of seniority and rigid pay scales will find it increasingly difficult to attract and retain competent new teachers of technology related fields such as science and mathematics. Scientific education in California is now largely conducted by older teachers. Keeping their skills current is difficult and when they retire replacing them will prove to be costly.

No Growth Policies

One of the most serious challenges to technology development in this stats in the 1980s is California's anti-growth ethic. The currently unstated, but effective, California growth policy is to limit growth by local limits on housing. This effective rationing of housing has led to California housing prices nearly twice the national level. These housing prices have already limited the expansion of the electronics industry in the area immediately around "Silicon Valley." It is also affecting the growth of other industries. High housing prices also redirect growth away from blue collar and clerical occupations toward high-income professional occupations. The result is a policy that effectively discriminates along social, ethnic, and income lines.

Decentralization

California, like the nation, is developing a pattern of great differences in economic health among its several regions. Even though the state as a whole is doing well, much of the Central Valley and the North Coast have severe unemployment problems. At the same time as some areas of California are in trouble, California high technology firms are spinning off new plants to other states and other nations. Potential new California locations for high technology industrial growth are being skipped over.

State leadership can solve this problem. There are several medium size California cities that are being skipped over for simple lack of information or for lack of local infrastructure to support new industry. A coordinated transportation planning, university planning, and industrial location strategy could help California's pockets of unemployment, help industrial growth, and relieve some of the growth pressures in such areas as Santa Clara and Orange counties. These would offer benefits not only to the state, but to the firms involved who would typically like to keep facilities as near as possible to the center of technology development.

Conclusion

The new technologies of the 1980s will continue to shift California toward more highly technical industries. California is likely to grow as a world technical leader. In general, this will help the expansion of California employment at least through 1990. However, the rates of change among industries, within industries, and among occupations are likely to be even greater in the 1980s than it was in the 1970s. Therefore, California state government should focus increased attention to identifying and planning to support humane transitions and the social infrastructure necessary so that all Californians can share in the benefits of our technical success.